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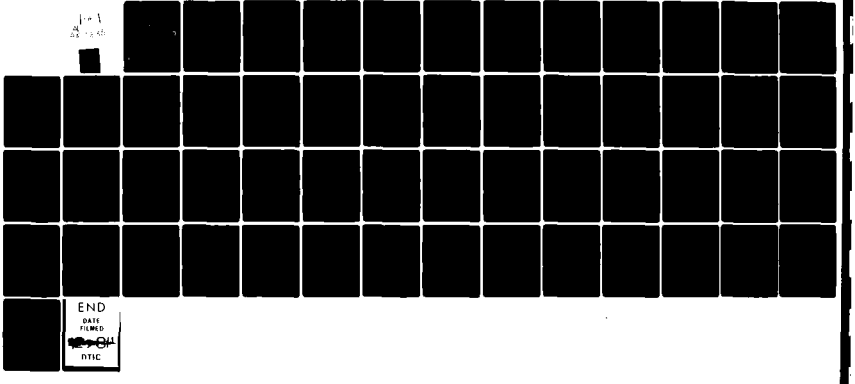

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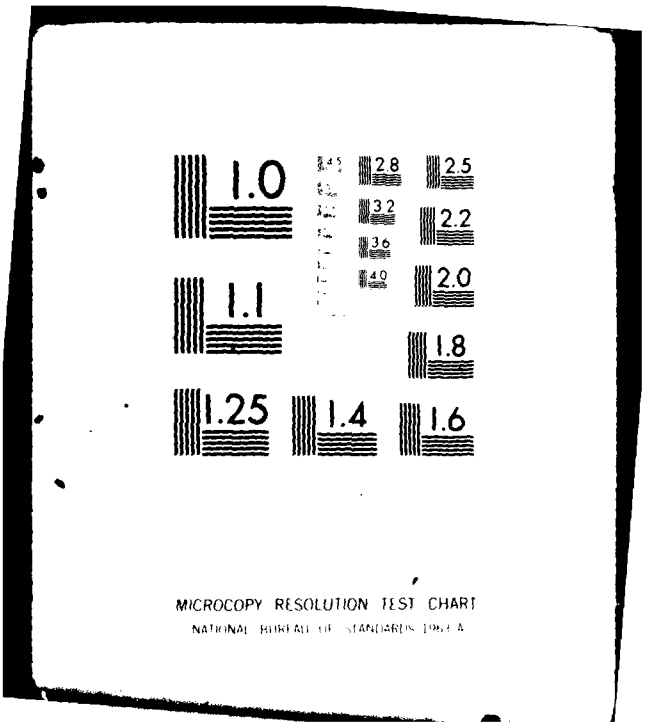
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This study analyzed the time series of second destination tonnage and suggests models to forecast them. An assortment of models were attempted including: exponential smoothing, polynominal regression, and Box-Jenkins, and the author found that a range of models can be used to forecast tonnage.

The models were applied to eleven tonnage series, and two different types of forecasting models were recommended based on the principal of cost-effectiveness; single exponential smoothing for nine of the series, and decomposition (cont.)

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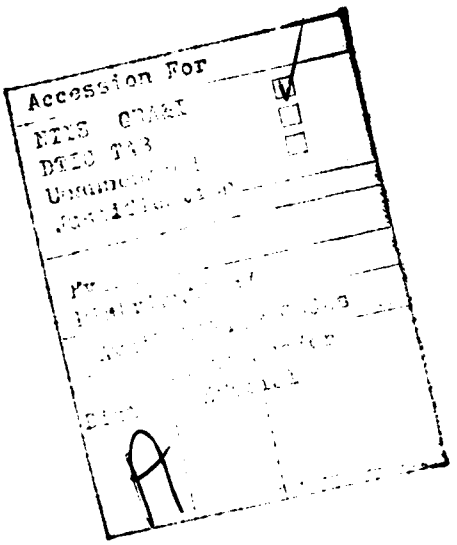
of the remaining two. There is no implementation cost in terms of computer programming or training in following these recommendations. Only two values are stored for exponential smoothing--the current tonnage and the forecast for current period. Time series decomposition requires the use of seasonal indices only. Seasonal indices are provided by the author.



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FORECAST OF THE SECOND DESTINATION TRANSPORTATION TONNAGE FOR THE AIR FORCE

FINAL REPORT

February, 1979

This research was conducted under Contract F33615-78-C-5214 for the Air Force Business Research Management Center, Wright-Patterson AFB, Ohio. The views expressed herein are solely the views of the authors and do not represent those of the United States Air Force.

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SUMMARY AND RECOMMENDATIONS

The purpose of this study was to analyze the time series of the second destination tonnage and to suggest models to forecast them. The time series models to be attempted were: exponential smoothing, polynomial regression, and Box-Jenkins. A structural "regression" model using overseas flying hours as the independent variable was also to be attempted.

Table 1 gives the assortment of models we used. It can be ascertained that we examined more models that originally contemplated. The reason was some special problems with the sealift series: seasonality in some cases; and the confounding of the series by the change of the fiscal year in 1977.

An inspection of Table 1 reveals that a range of models can be used to forecast tonnage, the models themselves spanning the very simple to the extremely sophisticated. The simplest model used was that of the sample mean. This was then extended to provide high-low estimates. The most complicated model used was the Wiener-Kolmogorov method, an autoregressive spectral analysis technique.

In recommending one forecasting model for any one tonnage series, we have to adhere to the principle of cost-effectiveness. That is, if we recommend a forecasting technique to you, we wish it to be relatively accurate and at the same time we would like it to cost you as little as possible. This principle has led us to recommend the two types of models listed in Table 2: single exponential smoothing for nine of the eleven tonnage series; and time series decomposition for the remaining two. There is no implementation cost in terms of computer programming or training in following these recommendations. For exponential smoothing, one need only store two values: the current tonnage and the forecast for the current period. As for time series decomposition,

one need only use the seasonal indices that we have already calculated. These indices may be adjusted from time to time, according to the judgment of the manager.

TABLE 1

MENU OF FORECASTING MODELS--SECOND DESTINATION TONNAGE

Series No.	Series	MODELS RECOMMENDED												
					Brown's Exponential Smoothing			Regression				Box-Jenkins Models		Decomposition, Winters or WK
		Sample Mean, $\bar{X}_t$	95% C.I. for μ_{xt}	95% Prob. Int. for X_t	Single	Linear	Quadratic	Vs. OSFH (all data)	Vs. OSFH (recent data)	Linear Vs. Time	Quadratic Vs. Time	(1,0,0)	Other Models	
1	PAC/AIR	Yes (6.9%)	Yes	Yes	Yes (0.7%)	Yes (1.3%)	Yes (4.8%)	Yes: R^2 = 0.94 (-18.0%)	No: R^2 = 0.03 (-6.3%)	No: R^2 = 0 (6.2%)	No: R^2 = 0.07 (0.4%)	Yes (4.7%)		Yes (***) (11.4%)
2	ATA/AIR	Yes (-9.2%)	Yes	Yes	Yes (-1.4%)	Yes (0.7%)	Yes (3.9%)	No: R^2 = 0	No: R^2 = 0.09 (8.8%)	No: R^2 = 0.03 (-4.2%)	Yes: R^2 = 0.23 (13.5%)	Yes (-11.5%)		Yes (****) (-0.5%)
3	NE/AIR	Yes (-20.1%)	Yes	Yes	Yes (-3.0%)	No	No	Yes: R^2 = 0.50 (-14.2%)	Yes: R^2 = 0.40 (6.6%)	No: R^2 = 0.04	No: R^2 = 0.01	Yes (-22.8%)		Yes (****) (1.8%)
4	EUR/AIR	Yes (-9.1%)	Yes	Yes	Yes (6.0%)	Yes (13.5%)	Yes (-7.0%)	No: R^2 = 0.03 (2.0%)	Yes: R^2 = 0.42 (0.6%)	No: R^2 = 0	No: R^2 = 0.13	Yes (-8.7%)		Yes (****) (-17.8%)
5	SOUTH/AIR	Yes (-9.7%)	Yes	Yes	Yes (-10.3%)	No	No	No: R^2 = 0	No: R^2 = 0.01 (-11.9%)	No: R^2 = 0 (-6.2%)	No: R^2 = 0.02 (30.9%)	Yes (-15.5%)		
6	PAC/SEA	No	No	No	Yes (4.9%)	No	No	Yes: R^2 = 0.61 (-91.6%)	Yes: R^2 = 0.41 (-27.5%)	Yes: R^2 = 0.76 (-3.8%)	Yes: R^2 = 0.77 (-9.6%)	Yes (-26.3%)	(4,1,0); (4,1,1) (-19.5%) (-16.7%)	
7	ATA/SEA	No	No	No	Yes (16.5%)	Yes (11.2%)	Yes (6.7%)	Yes: R^2 = 0.41 (-18.0%)	No: R^2 = 0.01 (8.3%)	Yes: R^2 = 0.55 (37.8%)	Yes: R^2 = 0.63 (2.6%)	Yes (6.4%)		
8	NE/SEA	No	No	No	No	No	No	No: R^2 = 0.04	No: R^2 = 0	No: R^2 = 0	No: R^2 = 0	No		Yes (*) (-115.1%)
9	EUR/SEA	No	No	No	Yes (-13.2%)	Yes (-22.2%)	Yes (-20.6%)	No: R^2 = 0	No: R^2 = 0 (-18.3%)	Yes: R^2 = 0.66 (-18.2%)	Yes: R^2 = 0.70 (-2.1%)	No	(1,1,0) + (1,0,0) Yes: (12.3%)	Yes (**) (22.1%)
10	SOUTH/SEA	No	No	No	No	No	No	Yes: R^2 = 0.39 (47.8%)	Yes: R^2 = 0.23 (35.0%)	Yes: R^2 = 0.39 (63.0%)	Yes: R^2 = 0.54 (38.7%)	No	(2,1,0) + (1,0,0)S Yes: (37.4%)	Yes (*) (25.6%)
11	CONUS	Yes (-25.7%)	Yes	Yes	Yes (-19.7%)	Yes (-10.4%)	Yes (-11.1%)	Vs. WFH No: R^2 = 0	Vs. WFH No: R^2 = 0.05 (-13.6%)	No: R^2 = 0 (-26.7%)	No: R^2 = 0 (-26.9%)	Yes (-33.6%)	(2,1,0) + (1,0,0)S Yes: (37.8%)	Yes (**) (17.6%)

The percentage in parenthesis is the error for one-step-ahead forecast (July '78 or 3rd Qtr., '78)

C.I. ≙ confidence interval; OSFH ≙ Overseas Flying Hours; WFH ≙ Worldwide Flying Hours

WK ≙ the Wiener-Kolmogorov Spectral Model

(*) indicates the classical time series decomposition model

(**) indicates the Winters exponential smoothing decomposition model

(***) indicates the WK model

(****) indicates the truncated WK model

TABLE 2

FORECASTING MODELS RECOMMENDED

Series	Name	Model	Forecasting Model
#1	PAC/AIR	Single Exponential Smoothing	$S_{t+1} = 0.60X_t + 0.40S_t$
#2	ALA/AIR	"	$S_{t+1} = 0.24X_t + 0.76S_t$
#3	NE/AIR	"	$S_{t+1} = 0.65X_t + 0.35S_t$
#4	EUR/AIR	"	$S_{t+1} = 0.49X_t + 0.51S_t$
#5	SOUTH/AIR	"	$S_{t+1} = 0.10X_t + 0.90S_t$
#6	PAC/SEA	"	$S_{t+1} = 0.99X_t + 0.01S_t$
#7	ALA/SEA	"	$S_{t+1} = 0.42X_t + 0.58S_t$
#8	NE/SEA	Time Series Decomposition	See Annex F for the seasonal index
#9	EUR/SEA	Single Exponential Smoothing	$S_{t+1} = 0.42X_t + 0.58S_t$
#10	SOUTH/SEA	Time Series Decomposition	See Annex F for the seasonal index
#11	CONUS	Single Exponential Smoothing	$S_{t+1} = 0.60X_t = 0.40S_t$

Symbols:

S_{t+1} is the forecast made in period t for period t + 1

X_t is the actual value realized in period t

S_t is the forecast made in period t - 1 for period t

ANNEX A

PLOT OF THE MODIFIED DATA AND THE DEVELOPMENT OF LOW-HIGH FORECASTS FOR THE STATIONARY SERIES

Exhibit A provides a plot of the tonnage data versus time. This is given for the eleven sets of tonnage series provided.

The plot of the data leads us to recommend forecasting models to use in each case. Series #1 (PAC/AIR) appears as a random walk; i.e., it is a stationary process. Hence, a ninety-five percent probability interval giving low-high forecasts would be appropriate. We shall also use other models for forecasting this series: single exponential smoothing; and some selected Box-Jenkins models. Similarly, Series #8 (NE/SEA) exhibits a seasonal component; witness the spikes during the July/August/September quarter. Consequently, we would recommend the use of a decomposition model. And so on!

The recommendations concerning the models to use are listed in Table A.1. Also listed are relevant information including the number of observations, N. We have censored the last three observations of each monthly series for purposes of comparing forecasts to actuals. These observations would be for July, August, and September of 1978. For the quarterly data, we censored the third and fourth quarters of 1978.

EXHIBIT A

PLOT OF THE DATA

VERSUS TIME

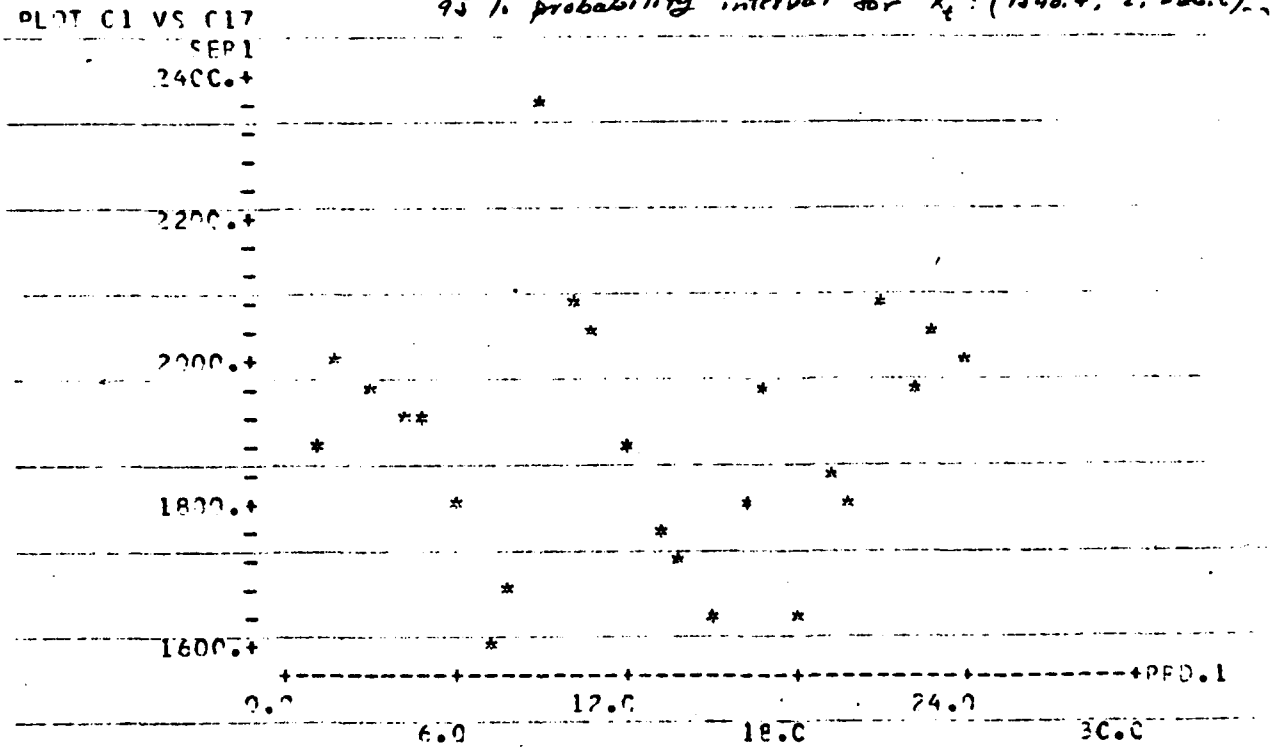
PAC AIRLIFT (MONTHLY)
Series #1
July '76 - June '78

INTERVAL WITH 95 PERCENT CONFIDENCE FOR C1
SER1 N = 24 MEAN = 1888.5 ST.DEV. = 178.

95.00 PERCENT C.I. FOR MU IS (1813.5265, 1963.5559)

95 % probability interval for x_t : (1540.4, 2, 236.6)

PLOT C1 VS C17



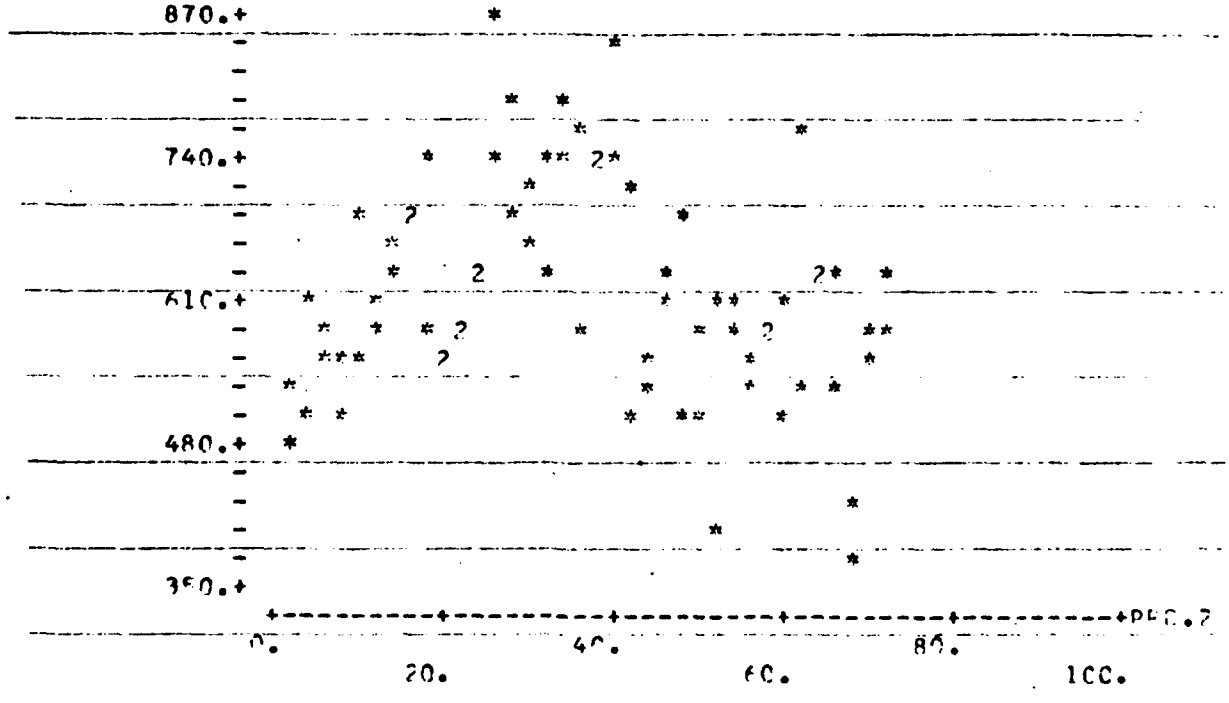
ALA AIRLIFT (MONTHLY)
Series #2
July '72 - June '78

INTERVAL WITH 95 PERCENT CONFIDENCE FOR C2
SER2 N = 72 MEAN = 617.10 ST.DEV. = 98.5

A 95.00 PERCENT C.I. FOR MU 'S (592.9545, 640.2303)

95% probability interval for X_t: (429.0, 810.2)

PLOT C2 VS CIB
SER2



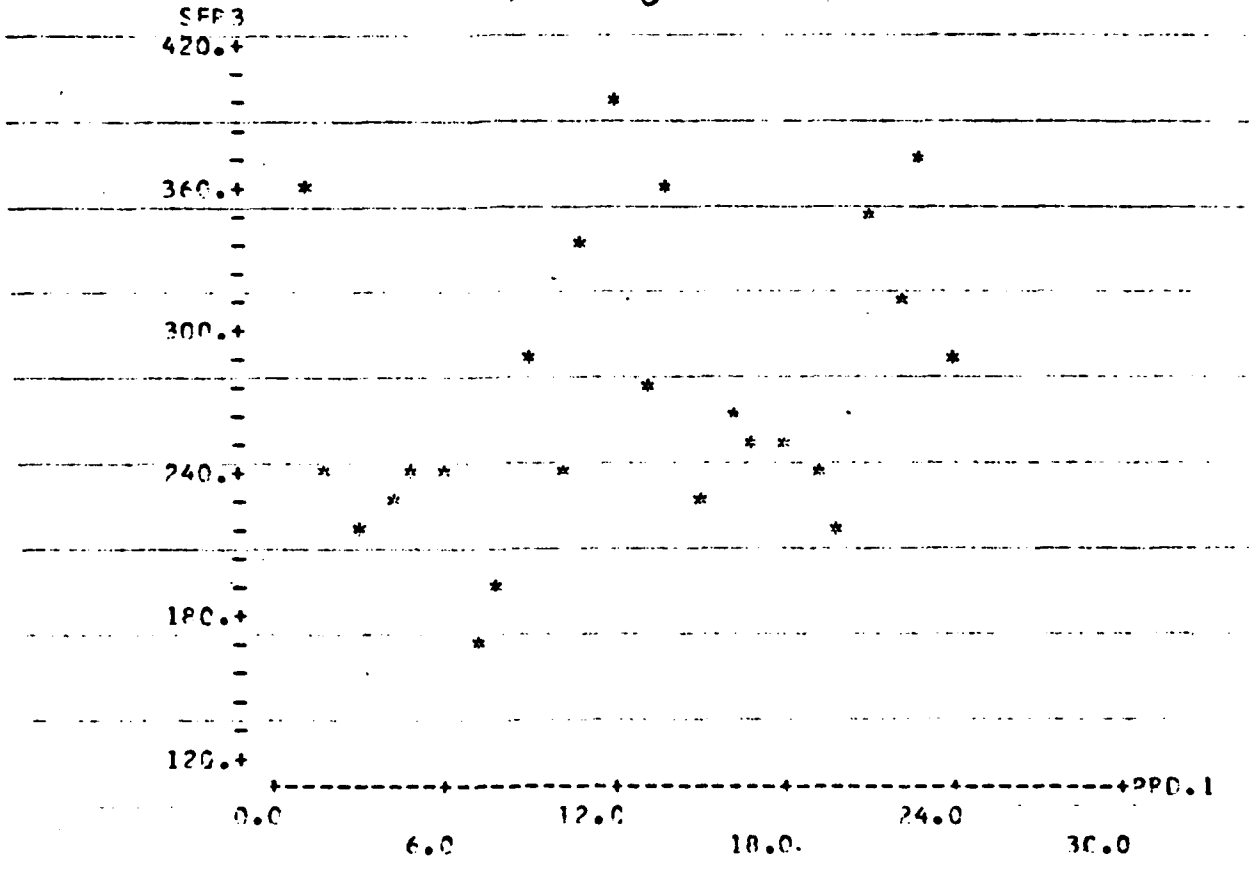
NE AIRLIFT (MONTHLY)
Series #3
July '76 - June '78

TINTERVAL WITH 95 PERCENT CONFIDENCE FOR C3 0

SER3 N = 24 MEAN = 273.75 ST.DEV. = 61.4

A 95.00 PERCENT C.I. FOR MU IS (247.8265, 299.6731)

PLOT C3 VS C17 95% probability interval for x_t : (143.4, 394.1) 0



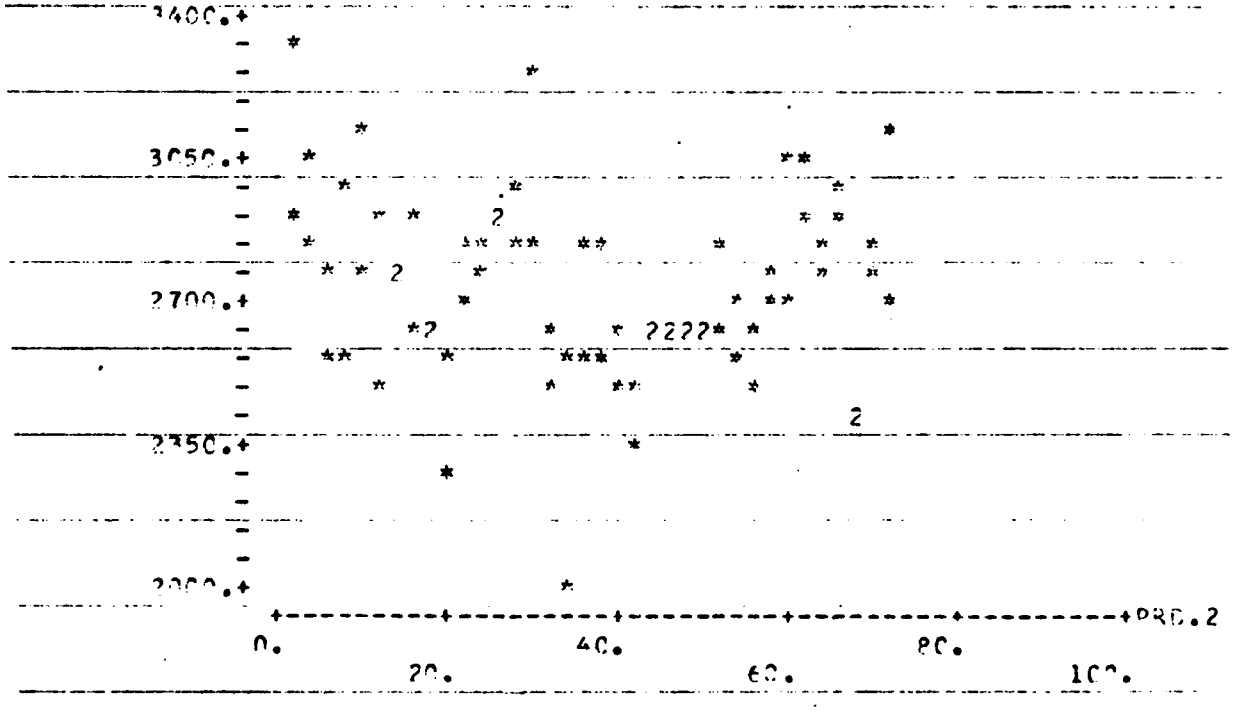
EUR AIRLIFT (MONTHLY)
Series #4
July '72 - June '78

TINTERVAL WITH 95 PERCENT CONFIDENCE FOR C4
SER4 N = 72 MEAN = 2732.2 ST.DEV. = 223.

A 95.00 PERCENT C.I. FOR MU IS (2679.8743, 2784.5658)

95% probability interval for X_t: (2,295.1, 3169.3)

PLOT C4 VS C18
SER4



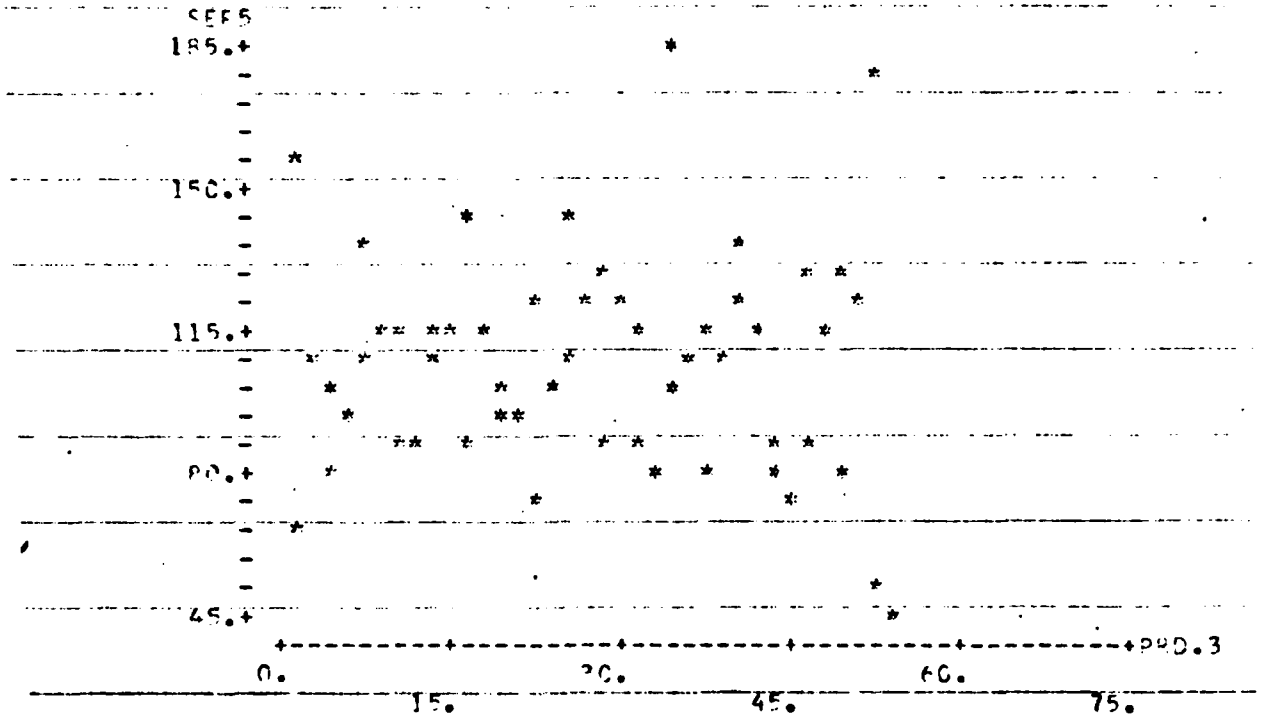
SOUTH AIRLIFT (MONTHLY)
Series #5
Jan. '74 - June '78

INTERVAL WITH 95 PERCENT CONFIDENCE FOR C5
SERS N = 54 MEAN = 106.43 ST.DEV. = 27.0

A 95.00 PERCENT C.I. FOR MU IS (99.0547, 113.7973)

95% probability interval for Y_t : (53.5, 159.4)

PLOT C5 VS C19

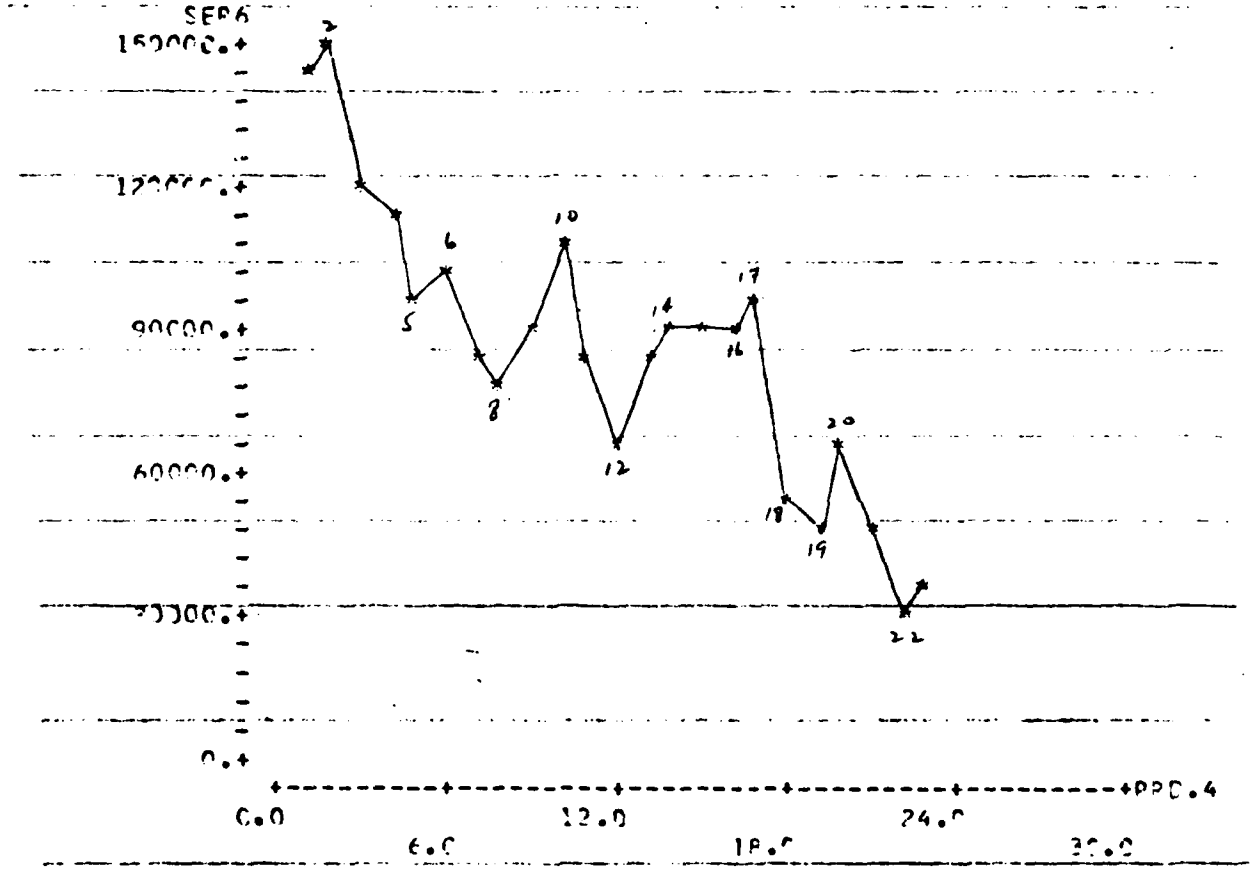


PAC SEALIFT (QUARTERLY)
Series #6
1st Qtr. '73 - 2nd Qtr. '78

INTERVAL WITH 95 PERCENT CONFIDENCE FOR C6
SER6 N = 23 MEAN = 8113. ST.DEV. = 31236.

AT 95.00 PERCENT C.I. FOR MU IS (71602.6250, 98623.8125)

PLOT C6 VS C20



ALA SEALIFT (QUARTERLY)
Series #7
1st Qtr. '73 - 2nd Qtr. '78

INTERVAL WITH 95 PERCENT CONFIDENCE FOR C7
SER7 N = 23 MEAN = 4727.2 ST.DEV. = 1761.

A 95.0% PERCENT C.I. FOR MU IS (3965.5464, 5488.8534)

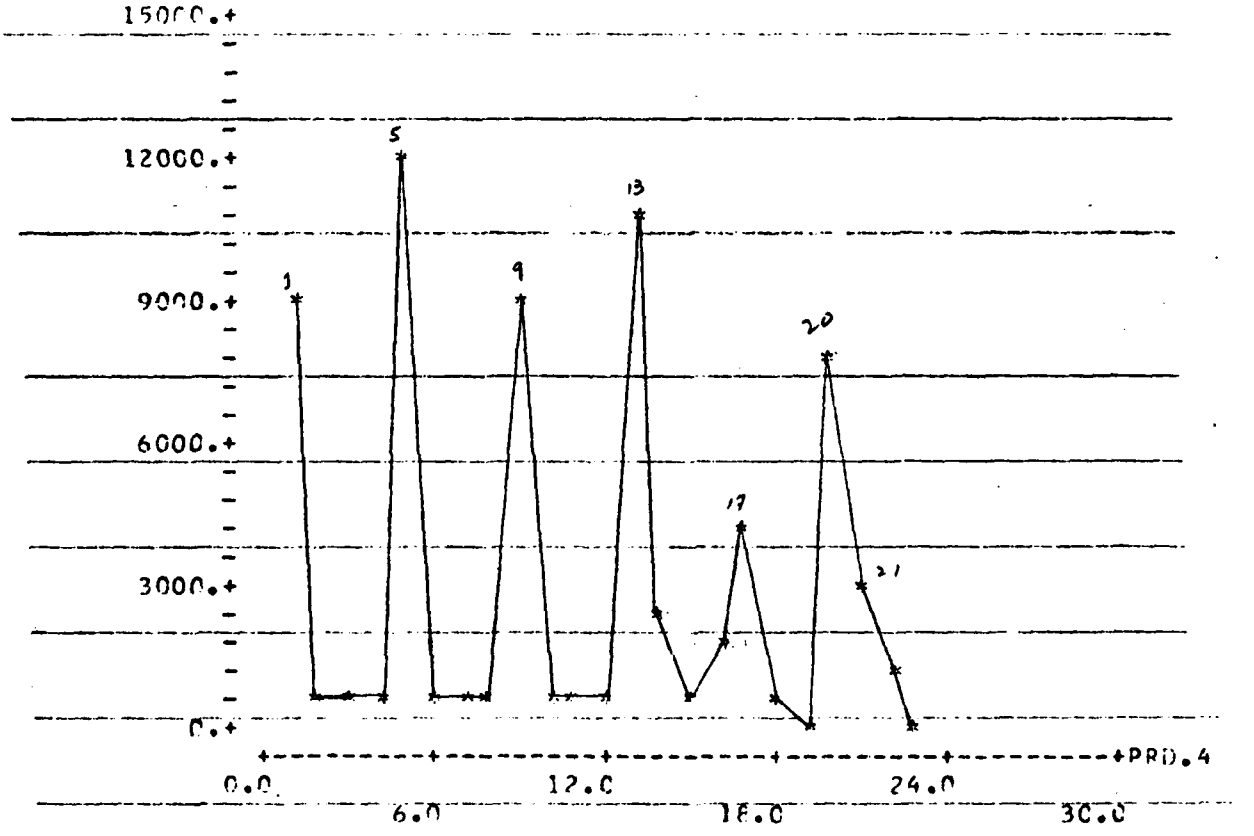
PLOT C7 VS C20
SER7
9500.+
8000.+
6500.+
5000.+
3500.+
2000.+
+----------+----------+----------+----------+----------+
0.0 6.0 12.0 18.0 24.0 30.0

NE SEALIFT (QUARTERLY)
Series #8
1st Qtr. '73 - 2nd Qtr. '78

TINTERVAL WITH 95 PERCENT CONFIDENCE FOR CR
SERR N = 23 MEAN = 2546.9 ST.DEV. = 3833.

A 95.00 PERCENT C.I. FOR MU IS (1288.8679, 4804.8672)

PLOT CR VS C20
SER8

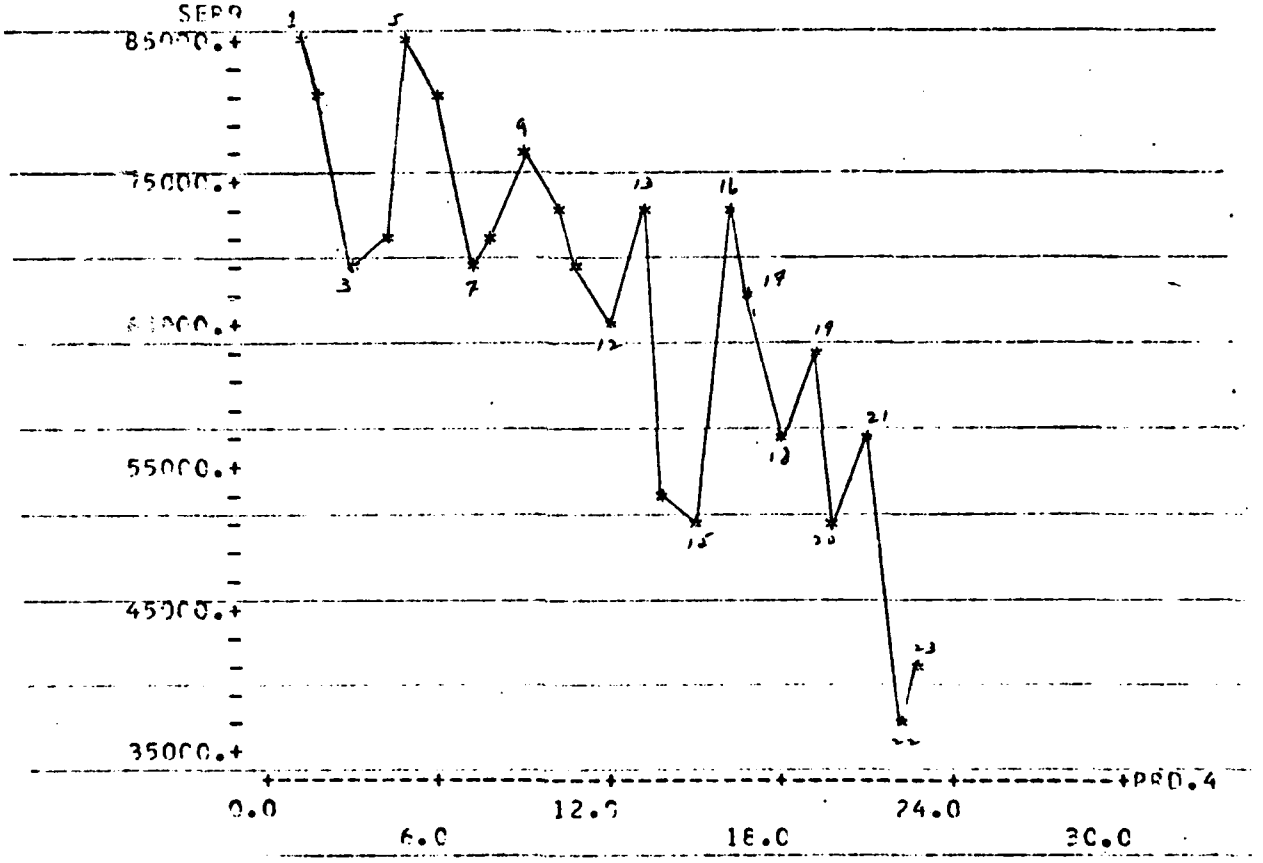


EUR SEALIFT (QUARTERLY)
Series #9
1st Qtr. '73 - 2nd Qtr. '78

TINTERVAL WITH 95 PERCENT CONFIDENCE FOR C9
SERS N = 23 MEAN = 66118. ST.DEV. = 13060.

A 95.00 PERCENT C.I. FOR MU IS (60466.7344, 71766.3750)

PLOT C9 VS C20
SERS



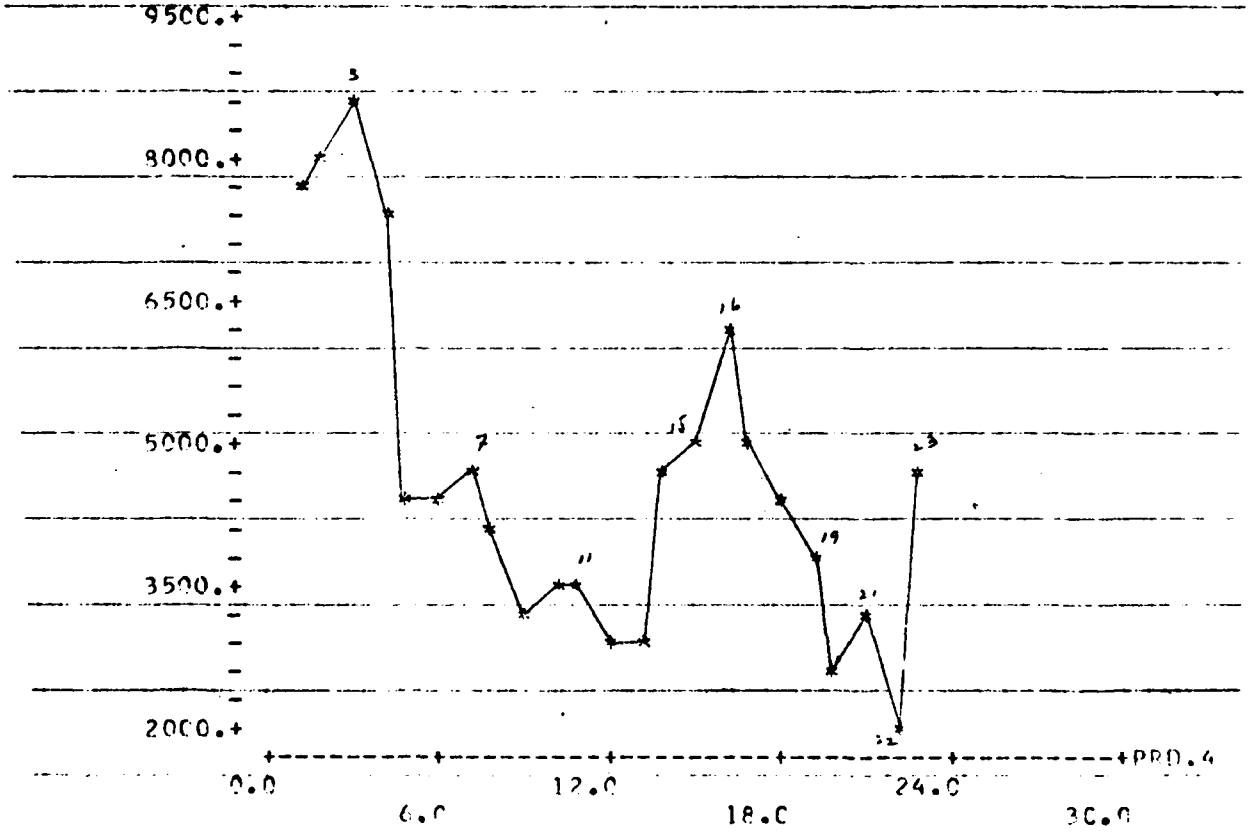
SOUTH SEALIFT (QUARTERLY)
Series #10
1st Qtr. '73 - 2nd Qtr. '78

13C

TINTERVAL WITH 95 PERCENT CONFIDENCE FOR C1C
SER10 N = 23 MEAN = 4674.5 ST.DEV. = 1806.

A 95.00 PERCENT C.I. FOR MU IS (3893.2250, 5455.0086)

PLOT C10 VS C20
SER10



CONUS (MONTHLY)
Series #11
July '74 - March '78

INTERVAL WITH 95 PERCENT CONFIDENCE FOR C11
SER11 N = 45 MEAN = 1897.8 ST.DEV. = 304.

A 95.00 PERCENT C.I. FOR MU IS (1806.5486, 1989.0063)

PLOT C11 VS C01 95% probability interval for Y_t. (1,302.0 ; 2,493.6)

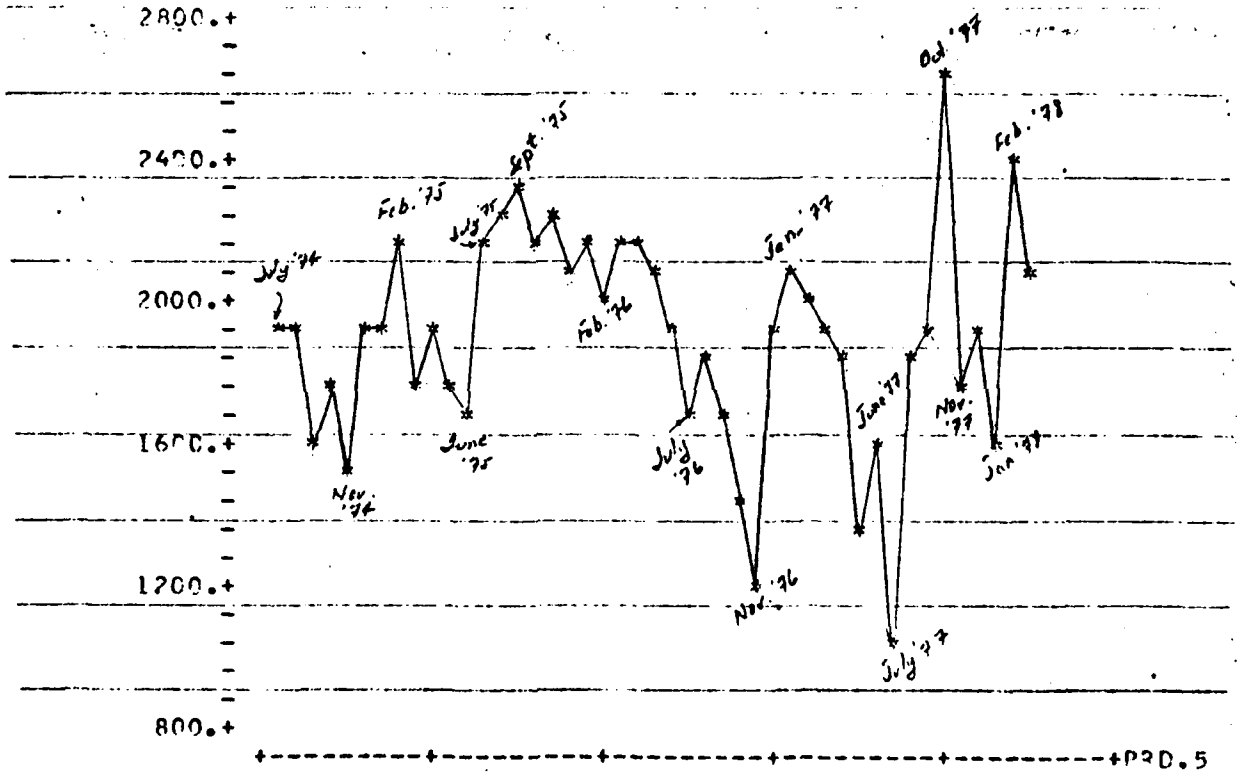


TABLE A.1

MONTHLY DATA: TIME SERIES MODELS

Series	Series No.	Start Date	End Date	N	Visual Identification	Models to Use
PAC/AIR	1	July 1976	June 1978	24	Random Walk	a. Probability Interval b. Single and Double Exp. Smoothing c. Selected Box-Jenkins Models
ALA/AIR	2	July 1972	June 1978	72	Random Walk or Quadratic	a. Probability Interval b. Single, Double, and Triple Exp. Smoothing c. Optimal Box-Jenkins Model
NE/AIR	3	July 1976	June 1978	24	Random Walk	a. Probability Interval b. Single Exponential Smoothing c. Selected Box-Jenkins Models
EUR/AIR	4	July 1972 (Modified Data)	June 1978	72	Random Walk	a. Probability Interval b. Single and Double Smoothing c. Optimal Box-Jenkins Model
SOUTH/AIR	5	Jan. 1974	June 1978	54	Random Walk	a. Probability Interval b. Single Exponential Smoothing c. Optimal Box-Jenkins Model
PAC/SEA	6	1st Qtr., 1973 (Corrected Data)	2nd Qtr., 1978	23	Curvilinear	a. Single & Double Exp. Smoothing b. Selected Box-Jenkins Models
ALA/SEA	7	" (Corrected Data)	"	23	Curvilinear	a. Single, Double, and Triple Exp. Smoothing b. Selected Box-Jenkins Models
NE/SEA	8	" (Corrected Data)	"	23	Seasonal	a. Time Series Decomposition Without Trend

TABLE A.1 (Continued)
MONTHLY DATA: TIME SERIES MODELS

Series	Series No.	Start Date	End Date	N	Visual Identification	Models to Use
EUR/SEA	9	1st Qtr., 1973 (Corrected Data)	2nd Qtr., 1978	23	Straight Line	a. 1st Order Polynomial b. Single, Double, and Triple Exp. Smoothing c. Selected Box-Jenkins Models
SOUTH/SEA	10	" (Corrected Data)	"	23	Complex with Some Seasonality	a. Decomposition Model b. Sinusoidal Model
CONUS	11	July 1974	March 1978	45	Random Walk or Quadratic	a. Probability Interval b. Single, Double and Triple Exp. Smoothing c. Optimal Box-Jenkins

ANNEX B

HIGH-LOW FORECASTS FOR THE RANDOM WALK MODEL

We can make the assumption that some of the tonnage series conform to the random walk model. These are: Series #1 - #5 and Series #11. The rest of the Series, #6 - #10, do not exhibit stationarity.

If we assume that the data for the stationary series are normally distributed, we can construct ninety-five percent probability intervals for the population values of the series. The lower limit of the interval would be considered as a low forecast; the higher limit of the interval would be a high forecast. Table B.1 gives these limits, calculated using the expression $\bar{X} \pm 1.96s$. (Note that this is different from constructing a ninety-five percent confidence interval for the population mean, in which case we would use the expression $\bar{X} \pm 1.96\ s/\sqrt{n}$.)

If we wished one value, rather than a high-low range of values, the best forecast would be the mean of the series, $\bar{X}$. We compare the mean of the series with the actuals for July 1978 in Table B.2. We see that the percentage error is relatively small. What is more important is that all the actuals for July 1978 are within the low-high limits given in Table B.1.

TABLE B.1

HIGH-LOW FORECASTS FOR SELECTED TONNAGE SERIES:
RANDOM WALK

Series No.	Series	Arithmetic Mean, $\bar{X}$ (tons)	Standard Deviation, s (tons)	Forecast (tons) Low	High
1	PAC/AIR	1,888.5	178	1,540.4	2,236.6
2	ALA/AIR	617.1	98.5	424.0	810.2
3	NE/AIR	273.8	61.4	143.4	394.1
4	EUR/AIR	2,732.8	223.0	2,295.1	3,169.3
5	SOUTH/AIR	106.4	27.0	53.5	159.4
6	PAC/SEA	85,113.0	31,236.0	Not Applicable	
7	ALA/SEA	4,727.2	1,761.0	Not Applicable	
8	NE/SEA	2,946.9	3,833.0	Not Applicable	
9	EUR/SEA	66,118.0	13,060.0	Not Applicable	
10	SOUTH/SEA	4,674.5	1,806.0	Not Applicable	
11	CONUS	1,897.8	304.0	1,302.0	2,493.6

TABLE B.2

PERCENTAGE ERROR IN ONE-STEP AHEAD FORECASTS USING THE RANDOM WALK MODEL

Series No.	Series	Arithmetic Mean, $\bar{X}$ (tons)	Actual for July '78	Percentage Error
1	PAC/AIR	1888.5	2,011	6.9
2	ACA/AIR	617.1	565	- 9.2
3	NE/AIR	273.8	228	-20.1
4	EUR/AIR	2732.8	2,506	- 9.1
5	SOUTH/AIR	106.4	97	- 9.7
11	CONUS	1897.8	1,475	-28.7

ANNEX C

EXPONENTIAL SMOOTHING MODELS

This annex presents the exponential smoothing forecasting models that performed best in making one-step-ahead forecasts. Table C.1 lists the eleven tonnage time series in question, the Brown exponential smoothing model used, the corresponding smoothing constant, the one-step-ahead forecast, and the percentage forecast error. Because some series such as NE/SEA (Series #8) did not fare well using Brown's model, another exponential smoothing procedure which incorporates trend and seasonality was used: this is the Winters model. Some results are shown in Table C.1A.

Table C.2 is developed from Tables C.1 and C.1A. It lists the feasible exponential smoothing models, based on one-step-ahead forecast errors. Table C.2 should serve as only a guide.

It may be of interest to note that the smoothing constants were found by means of a computer search. In effect, the smoothing constant was chosen so as to minimize the mean absolute deviation (MAD) of the historical data.

It may also be of interest to remark that for most of the tonnage series, the exponential smoothing models are robust to "data updates." For example, the percentage forecasting error has not changed considerably (except for CONSU--Series #17) when the actuals for July or 3rd Qtr. 1978 were updated.

TABLE C.1

RESULTS OF EXPONENTIAL SMOOTHING--BROWN'S MODEL

No.	Series	Type	N	Smoothing Model	Optimal Smoothing Constant, α	Forecast for July '78 or 3rd Qtr. '78	Actual for July '78 or 3rd Qtr. '78	Percentage Error
1	PAC/AIR (Chopped)	Monthly	24	Single	0.60	1996	2011	0.7
				Linear	0.30	2037	"	1.3
				Quadratic	0.06	1914	"	4.8
2	ALA/AIR	"	72	Single	0.24	573	565	- 1.4
				Linear	0.12	561	"	0.7
				Quadratic	0.06	543	"	3.9
3	NE/AIR (Chopped)	"	24	Single	0.65	235	228	- 3.0
4	EUR/AIR		72	Single	0.49	2356	2506	6.0
				Linear	0.26	2168	"	13.5
				Quadratic	0.10	2681	"	- 7.0
5	SOUTH/AIR (Chopped)	"	52 (March '74 - June '78)	Single	0.10	107	97	-10.3
6	PAC/SEA	Quarterly	23	Single	0.99	33341	35054	4.9
				Linear	0.38	27156		
				Quadratic	0.72	34959		0.3
7	ALA/SEA	"	23	Single	0.42	3194	3823	16.5
				Linear	0.36	3395		11.2
				Quadratic	0.25	3567		6.7
8	NE/SEA	"	23	Single	0.28	1899	318	Inadmissible Model
				Linear	0.18	1454		
				Quadratic	0.12	1313		
9	EUR/SEA	"	23	Single	0.42	45316	40047	-13.2
				Linear	0.15	48956		-22.2
				Quadratic	0.09	48297		-20.6

TABLE C.1
(Continued)

RESULTS OF EXPONENTIAL SMOOTHING--BROWN'S MODEL

No.	Series	Type	N	Smoothing Model	Optimal Smoothing Constant, α	Forecast for July '78 or 3rd Qtr. '78	Actual for July '78 or 3rd Qtr. '78	Percentage Error
10	SOUTH/SEA	"	23	Single	0.94	4425	7231	Inadmissible Model
				Linear	0.60	4599		
				Quadratic	0.72	5069		
11	CONUS (Chopped)	Monthly	45	Single	0.60	1766	1475	-19.7
				Linear	0.30	1628	"	-10.4
				Quadratic	0.02	1638	"	-11.1

TABLE C.1A

RESULTS OF EXPONENTIAL SMOOTHING (WINTERS' MODEL)

No.	Series	Type	N	Optimal Smoothing Constants α	β	γ	Forecast for July '78 or 3rd Qtr. '78	Actual for July '78 or 3rd Qtr. '78	Percentage Error
1	PAC/AIR	Monthly	24					2011	
2	ALA/AIR	"	72					565	
3	NE/AIR	"	24					228	
4	EUR/AIR	"	72					2506	
5	SOUTH/AIR	"	52					97	
6	PAC/SEA	Quarterly	23					35054	
7	ALA/SEA	"	23					3823	
8	NE/SEA	"	23	0.05	0.05	0.30	3205	318	--
9	EUR/SEA	"	23	0.05	0.30	0.30	48915	40047	22.1
10	SOUTH/SEA	"	23					7231	
11	CONUS	Monthly	45	0.10	0.10	0.30	1738	1475	17.8

TABLE C.2

FEASIBLE EXPONENTIAL SMOOTHING MODELS

Series	Model	Smoothing Constant	Brown's One-Step-Ahead Forecast Error	Winter's One-Step-Ahead Forecast Error
PAC/AIR (Chopped)	Single	0.60	0.7%	
	Linear	0.30	1.3	
	Quadratic	0.06	4.8	
ALA/AIR	Single	0.24	- 1.4	
	Linear	0.12	0.7	
	Quadratic	0.06	3.9	
NE/AIR (Chopped)	Single	0.65	- 3.0	
EUR/AIR	Single	0.49	6.0	
	Linear	0.26	13.5	
	Quadratic	0.10	- 7.0	
SOUTH/AIR	Single	0.10	-10.3	
PAC/SEA	Single	0.99	4.9	
ALA/SEA	Single	0.42	16.5	
	Linear	0.36	11.2	
	Quadratic	0.25	6.7	
EUR/SEA	Single	0.42	-13.2	22.1
	Linear	0.15	-22.2	
	Quadratic	0.09	-20.6	
CONUS (Chopped)	Single	0.60	-19.7	17.8
	Linear	0.30	-10.4	
	Quadratic	0.02	-11.1	

Source: Table C.1 & C.2

ANNEX D

REGRESSION ON FLYING HOURS

In Interim Report No. 2, we used all the data that were available and regressed tonnage on flying hours. The results in terms of percentage error were disappointing, as seen in Table D.4. Consequently, we followed the suggestion that we regress only the most recent eight to ten observations. This we did in Interim Report No. 3. Table D.3A is a summary of this regression and Table D.4A presents the percentage errors. For purposes of comparison these tables are appended to Tables D.3 and D.4. It is seen that recent observations give better results in terms of percentage error, but that in many of these cases the R^2 is zero or near-zero. A small R^2 says that there is no relationship between tonnage and flying hours.

What does it mean when the R^2 is very small but when the regression equation developed gives good forecasts? It means that an average value for recent tonnages would by itself be a good forecast; that in these circumstances the knowledge of flying hours does not help.

TABLE D.1

CODE USED IN REGRESSION ON FLYING HOURS

MILITARY AIRLIFT COMMAND TONNAGE		MONTHLY DATA
PAC	C1	
ALA	C2	
NE	C3	
EUR	C4	
SOUTH	C5	
MILITARY AIRLIFT COMMAND TONNAGE		AGGREGATED QUARTERLY DATA
PAC/AIR	C17	
ALA/AIR	C18	
NE/AIR	C19	
EUR/AIR	C20	
SOUTH/AIR	C21	
MILITARY SEALIFT COMMAND TONNAGE		QUARTERLY DATA
PAC/SEA	C6	
ALA/SEA	C7	
NE/SEA	C8	
EUR/SEA	C9	
SOUTH/SEA	C10	
CONTINENTAL US (CONUS) TONS		MONTHLY DATA
CONUS	C11	
OVERSEAS FLYING HOURS (OSFH)		QUARTERLY DATA
PAC	C12	
ALA	C13	
NE	C14	
EUR	C15	
SOUTH	C16	
SEA PLUS AIRLIFT COMMANDS TONNAGE		AGGREGATED QUARTERLY DATA
PAC-AGG	C30	
ALA-AGG	C31	
NE-AGG	C32	
EUR-AGG	C33	
SOUTH-AGG	C34	

TABLE D.2

QUARTERLY DATA: REGRESSING TONNAGE ON OVERSEAS FLYING HOURS (OSFH) -- ALL DATA

Tonnage Series	Overseas Flying Hrs. Series	Start Date	End Date	N	Visual Identification	Regression Models to Use
PAC/AIR C17 vs. C12	PAC/OSFH	1st Qtr. '73	3rd Qtr. '78	24	Linear Trend	Straight Line
ALA/AIR C18 vs. C13	ALA/OSFH	"	"	"	No Discernible Relationship	--
NE/AIR C19 vs. C14	NE/OSFH	"	"	23	Linear Trend (Delete first quarter outlier)	Straight Line
EUR/AIR C20 vs. C15	EUR/OSFH	"	"	24	Linear Trend (?)	Straight Line
SOUTH/AIR C21 vs. C16	SOUTH/OSFH	"	"	"	No Discernible Relationship	--
PAC/SEA C6 vs. C12	PAC/OSFH	"	"	"	Quadratic	a. Straight Line b. Parabola
ALA/SEA C7 vs. C13	ALA/OSFH	"	"	"	Linear Trend	Straight Line
NE/SEA C8 vs. C14	NE/OSFH	"	"	"	Linear Trend (?)	Straight Line
EUR/SEA C9 vs. C15	EUR/OSFH	"	"	"	No Discernible Relationship	--
SOUTH/SEA C10 vs. C16	SOUTH/OSFH	"	"	"	Linear Trend	Straight Line
PAC-AGG C30 vs. C12	PAC/OSFH	"	"	"	Quadratic	a. Straight Line b. Parabola
ALA-AGG C31 vs. C13	ALA/OSFH	"	"	"	Linear Trend	Straight Line
NE-AGG C32 vs. C14	NE/OSFH	"	"	23	Linear Trend (Delete first quarter outlier)	Straight Line
EUR-AGG C33 vs. C15	EUR/OSFH	"	"	24	No Discernible Relationship	--
SOUTH-AGG C34 vs. C16	SOUTH/OSFH	"	"	"	Linear Trend	Straight Line
CONUS-AGG	Worldwide Flying Hours (WFH)	"	"	"	No Discernible Relationship	--

TABLE D.3

QUARTERLY DATA: REGRESSION EQUATIONS, TONNAGE VS. OVERSEAS FLYING HRS.--ALL DATA

Tonnage, Y	Overseas Flying Hrs., X	Adjusted R^2	Regression Equation	$S_{y \cdot x}$
PAC/AIR C17 vs. C12	PAC/OSFH	94.3%	Y = 4055 + 0.0905X (Recommended)	1,882
ALA/AIR C18 vs. C13	ALA/OSFH		No discernible relationship	
NE/AIR C19 vs. C14	NE/OSFH	50.2	Y = 96.3 + 0.704X (Recommended)	263
EUR/AIR C20 vs. C15	EUR/OSFH	3.2	Y = 6415 + 0.0323X (Not recommended)	815
SOUTH/AIR C21 vs. C16	SOUTH/OSFH		No discernible relationship	
PAC/SEA C6 vs. C12	PAC/OSFH	61.4	Y = 56718 + 0.300X (Recommended; second order polynomial not statistically significant)	19,917
ALA/SEA C7 vs. C13	ALA/OSFH	40.9	Y = -2420 + 0.740X (Recommended)	1,343
NE/SEA C8 vs. C14	NE/OSFH	3.6	Y = -905 + 2.28X (Not recommended)	3,719
EUR/SEA C9 vs. C16	EUR/OSFH		No discernible relationship	
SOUTH/SEA C10 vs. C16	SOUTH/OSFH	39.0	Y = 2427 + -.873X (Recommended)	1,426
PAC/AGG C30 vs. C12	PAC/OSFH	71.1	Y = 60773 + 0.391X (Recommended; second order polynomial not statistically significant)	20,949
ALA/AGG C31 vs. C12	ALA/OSFH	39.1	Y = -460 + 0.729X (Recommended)	1,370
NE-AGG C32 vs. C14	NE/OSFH	(No statistically significant linear relationship found)		

TABLE D.3 (Continued)
QUARTERLY DATA: REGRESSION EQUATIONS, TONNAGE VS. OVERSEAS FLYING HRS.--ALL DATA

Tonnage, Y	Overseas Flying Hrs., X	Adjusted R^2	Regression Equation	$S_{y \cdot x}$
EUR-AGG C33 vs. C15	EUR/OSFH		No discernible relationship	
SOUTH-AGG C34 vs. C16	SOUTH/OSFH	43.8%	Y = 2579 + 0.987X	1,466
CONUS-AGG	Worldwide Flying Hrs. (WFH)		No discernible relationship	

TABLE D.3A

QUARTERLY DATA: REGRESSION EQUATIONS, TONNAGE VS. OVERSEAS FLYING HOURS--RECENT OBSERVATIONS

Tonnage Y	No. of Observations N	r	R^2	Regression Equation	$s_{y.x}$
PAC/AIR C17 vs. C12	8	-0.184	0.03	Y = 6,672 - 0.0293X	323
ALA/AIR C18 vs. C13	8	-0.295	0.09	Y = 2,310 - 0.0707X	181
NE/AIR C19 vs. C14	8	0.631	0.40	Y = 207 + 0.489X	93
EUR/AIR C20 vs. C15	10	0.649	0.42	Y = 3,963 + 0.0723X	695
SOUTH/AIR C21 vs. C16	8	0.117	0.01	Y = 294 + 0.0123X	53
PAC/SEA C6 vs. C12	7	-0.645	0.41	Y = 259,131 - 6.15X	1,288
ALA/SEA C7 vs. C13	10	-0.102	0.01	Y = 4,852 - 0.144X	1,092
NE/SEA C8 vs. C14	8	0	0	Y = -65 + 1.76X	2,911
EUR/SEA C9 vs. C15	8	-0.504	0.25	Y = 98,730 - 0.798X	10,063
SOUTH/SEA C10 vs. C16	8	-0.476	0.23	Y = 6,814 - 1.55X	1,457
PAC/AGG C30 vs. C12	7	-0.641	0.41	Y = 265,000 - 6.15X	10,392
ALA/AGG C31 vs. C13	8	-0.001	0	Y = 5,217 - 0.0022X	1,378
NE/AGG C32 vs. C14	8	0.116	0.01	Y = 142 + 2.25X	2,970
EUR/AGG C33 vs. C15	8	-0.455	0.21	Y = 100,000 - 0.688X	9,912
SOUTH/AGG C34 vs. C16	8	-0.476	0.23	Y = 7,108 - 1.54X	1,444
CONUS/AGG vs. WFH	8	0.226	0.05	Y = 4,031 + 0.0021X	700

Note

The R^2 is not corrected for degrees of freedom

TABLE D.4

PREDICTION OF 1978 3RD QTR TONNAGE USING OVERSEAS FLYING HOURS (OSFH)--ALL DATA

Quarterly Series	Regression Equation	3rd Qtr '78 OSFH (X)	Predicted 3rd Qtr '78 Tonnage (Y)	R^2	Actual 3rd Qtr '78 Tonnage	% Error
PAC/AIR	Y = 4055 + 0.0905X	34,865	7120	0.943	6033	-18.0
NE/AIR	Y = 96.3 + 0.704X	1,476	1135	0.502	994	-14.2
EUR/AIR	Y = 6415 + 0.0323X	64,399	8495	0.032	8664	2.0
PAC/SEA	Y = 56,718 + 0.300X	34,865	67178(?)	0.614	35054	-91.6
ALA/SEA	Y = -2420 + 0.740X	9,365	4510	0.409	3823	-18.0
NE/SEA	Y = -905 + 2.28X	1,476	2460	0.036	318	--
SOUTH/SEA	Y = 2427 + 0.873X	1,363	3617(?)	0.390	6927	47.8
PAC/AGG	Y = 60773 + 0.391X	34,865	74405	0.711	41087	--
SOUTH/AGG	Y = 2579 + 0.985X	1,363	3921	0.438	2934	-33.6

TABLE D.4A

PREDICTION OF 1978 3RD QUARTER TONNAGE USING OVERSEAS FLYING HOURS (OSFH)--RECENT OBSERVATIONS

Quarterly Series	Regression Equation	3rd Qtr. '78 OSFH (X)	Predicted 3rd Qtr. '78 Tonnage (Y)	R^2	Actual 3rd Qtr. '78 Tonnage	% Error
PAC/AIR	Y = 6,672 - 0.0293X	34,865	5,650	0.03	6,033	6.3
ALA/AIR	Y = 2,310 - 0.0707X	9,365	1,648	0.09	1,807	8.8
NE/AIR	Y = 207 + 0.489X	1,476	928	0.40	994	6.6
EUR/AIR	Y = 3,963 + 0.0723X	64,339	8,614	0.42	8,664	0.6
SOUTH/AIR	Y = 294 + 0.0123X	1,363	311	0.01	278	-11.9
PAC/SEA	Y = 259,131 - 6.15X	34,865	44,693	0.41	35,054	-27.5
ALA/SEA	Y = 4,852 - 0.144X	9,365	3,505	0.01	3,823	8.3
NE/SEA	Y = -65 + 1.76X	1,476	2,533	0	318	--
EUR/SEA	Y = 98,730 - 0.798X	64,339	47,387	0	40,047	-18.3
SOUTH/SEA	Y = 6,814 - 1.55X	1,363	4,701	0.23	7,231	35.0
PAC/AGG	Y = 265,000 - 6.15X	34,865	50,580	0.41	41,087	-23.1
ALA/AGG	Y = 5,217 - 0.0022X	9,365	5,196	0	5,630	7.7
NE/AGG	Y = 142 + 2.25X	1,476	3,463	0.01	1,303	-165.8
EUR/AGG	Y = 100,000 - 0.688X	64,399	55,693	0.21	48,863	-14.0
SOUTH/AGG	Y = 7,108 - 1.54X	1,363	5,009	0.23	2,934	-70.7
CONUS/AGG Vs. WFH	Y = 4,031 + 0.0021X	709,030 (WFH)	5,519	0.05	4,857	-13.6

Notes

WFH $\sim$ Worldwide Flying Hours

The R^2 is not corrected for degrees of freedom

ANNEX E

BOX-JENKINS MODELS

Of the Box-Jenkins models attempted the most powerful group was the first-order autogressive model (1,0,0). The results for this model are given in Table E.1. The one-step-ahead percentage error for this model appears reasonable, in most cases. The Box-Jenkins (1,0,0) model was not applicable to series #8, #9, and #10 (NE/SEA, EUR/SEA, SOUTH/SEA) because of some obvious seasonal patterns in these. See Annex F for an explication on the seasonal patterns in some of the Sealift series.

We also attempted some other Box-Jenkins models in the hope that we would improve upon the (1,0,0) model. In some cases we could. In series #6 (PAC/SEA), for example, we reduced the one-step-ahead error from -26.3 percent for the (1,0,0) model to -16.7 percent for the (4,1,1) model.

TABLE E.1

FIRST ORDER AUTOREGRESSIVE MODEL: BOX-JENKINS (1,0,0)

No.	Series	Equation	Forecast for July '78 or 3rd Qtr. '78	Actual for July '78 or 3rd Qtr. '78	Percentage Error
1.	PAC/AIR	$X_t = 1334.1 + 0.2938X_{t-1}$	1,916	2,011	4.7
2.	ALA/AIR	$X_t = 305.7 + 0.5040X_{t-1}$	630	565	-11.5
3.	NE/AIR	$X_t = 197.5 + 0.2828X_{t-1}$	280	228	-22.8
4.	EUR/AIR	$X_t = 2028.8 + 0.2575X_{t-1}$	2,725	2,506	- 8.7
5.	SOUTH/AIR	$X_t = 116.1 - 0.0915X_{t-1}$	112	97	-15.5
6.	PAC/SEA	$X_t = 14872.8 + 0.8803X_{t-1}$ (Regression analysis)	44,267	35,054	-26.3
7.	ALA/SEA	$X_t = 2159.4 + 0.5440X_{t-1}$	3,578	3,823	6.4
8.	NE/SEA	Inadmissible Model because of Seasonality			
9.	EUR/SEA	"			
10.	SOUTH/SEA	"			
11.	CONUS	$X_t = 1214.59 + 0.3604X_{t-1}$	1,971	1,475	-33.6

TABLE E.2

OTHER BOX-JENKINS MODELS

Series No.	Series	Model (p.d.q.)	Forecast for July '78 or 3rd Qtr. '78	Actual for July '78 or 3rd Qtr. '78	Percent Error
1.	PAC/AIR				
2.	ALA/AIR				
3.	NE/AIR				
4.	EUR/AIR				
5.	SOUTH/AIR				
6.	PAC/SEA	(4,1,0)	41,899	35,054	-19.5
	"	(4,1,1)	40,907	"	-16.7
7.	ALA/SEA				
8.	NE/SEA				
9.	EUR/SEA	(1,1,0) (1,0,0) - for seasonality	35,114	40,047	12.3
	"	(3,1,1) (1,1,1) - for seasonality	60,970	40,047	-52.2
10.	SOUTH/SEA	(2,1,0) (1,0,0) - seasonality	4,530	7,231	37.4
	"	(2,1,0)* (1,0,0) - seasonality	4,501	7,231	37.8

*Constant term included

ANNEX F

TIME SERIES DECOMPOSITION FOR NE/SEALIFT (Series #8) and SOUTH/SEALIFT (Series #10)

The quarterly data of the Sealift series exhibits special problems: 1) Some of these series appear to be seasonal--witness the spikes every first quarter for series #8 (NE/Sealift); and 2) The change of the fiscal year in FY77 has confounded the recent data.

We wish to use a time series decomposition model on some of these series, particularly series #8 (NE/Sealift) and series #10 (SOUTH/Sealift). A decomposition model easily yields a seasonal index. But since there are two first quarters in FY77, we have decided to combine these into data for just one quarter. Thus, the number of the period would be consistent with its quarterly position in the fiscal year.

We now concentrate on NE/Sealift and SOUTH/Sealift. The two series, NE/Sealift and SOUTH/Sealift have posed special problems: most of the conventional time series models failed to forecast them accurately. An inspection of their plots exhibits seasonality; but the periodicity of the peaks and troughs becomes erratic toward the end of the series. Both series appear to lack a trend. (This is true for SOUTH/Sealift if we delete the data for the fiscal year 1973). A tentative way to handle these two series is to calculate for them seasonal indices by means of moving averages. These calculations are given in Tables F.1 - F.3 for NE/Sealift (series #8) and in Tables F.4 - F.6 for SOUTH/Sealift (series #10).

Tables F.7 and F.8 give the forecasts and forecast error for the third quarter of 1978. The forecast errors are high, and the seasonal indices may have to be adjusted if these errors persist.

TABLE F.1

TIME SERIES DECOMPOSITION: NEA/SEALIFT (Series #8)

Qtr., Yr.	Period	X_t	Four-quarter Moving Average	4×4 Centered Moving Average	Percentage of Centered Moving Average
1, '73	1	8.715		-	-
			-		
2, '73	2	508		-	-
			2,590.75		
3, '73	3	736		-	-
			3,486.50		
4, '73	4	404		3,288.69	12.28
			3,538.75		
1, '74	5	12,298		3,554.94	345.94
			3,538.75		
2, '74	6	717		3,391.69	21.14
			3,655.75		
3, '74	7	736		3,209.38	22.93
			2,833.50		
4, '74	8	872		3,020.69	28.87
			2,809.50		
1, '75	9	9,009		2,767.25	325.56
			2,784.00		
2, '75	10	621		2,822.13	22.00
			2,642.00		
3, '75	11	634		2,986.63	21.23
			3,052.50		
4, '75	12	304		3,142.06	9.68
			3,468.00		
1, '76	13	10,651		3,444.13	309.25
			3,405.75		
2, '76	14	2,283		3,236.25	70.54
			3,850.25		
3, '76	15	385		2,165.67	17.78
			2,310.75		
4, '76	16	2,082		2,898.81	71.82
			1,798.25		
1, '77	17*	4,493		2,908.60	154.47
			3,636.00		
2, '77	18	233		3,087.75	7.55
			3,889.25		
3, '77	19	7,736		3,394.25	227.91
			3,027.50		
4, '77	20	3,095		-	-
			3,024.25		
5, '77	21	1,046		-	-
			-		
6, '77	22	220		-	-

*Change in the fiscal year (1st Qtr. '75); combined tonnage

Source: Croxton, Cowden, and Klein, Applied General Statistics, Third edition, Englewood Cliffs, N.J.: Prentice-Hall, pp. 293-302.

TABLE F.2

PERCENTAGES OF CENTERED FOUR-QUARTER MOVING AVERAGES FOR SECOND DESTINATION TONNAGE, NE/SEALIFT (Series #8)

Fiscal Year	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
73	--	--	--	12.28
74	345.94	21.14	22.93	28.87
75	325.56	22.00	21	9.68
76	309.25	70.54	17.78	71.82
77	154.47	7.55	227.91	--

Source: Table F.1

TABLE F.3

ARRAY OF PERCENTAGES

Rank	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Mean
1	345.94	70.54	227.91	71.82	--
2	325.56	22.10	22.93	28.87	--
3	309.25	21.14	21.23	12.28	--
4	154.47	7.55	17.78	9.68	--
Mean of ranks 2 & 3	317.4	21.6	22.1	20.6	95.4
Seasonal index	332.6	22.6	23.2	21.6	100.0

Source: Table F.2

TABLE F.4

TIME SERIES DECOMPOSITION: SOUTH SEALIFT (Series #8)

Qtr., Yr.		Period	X_t	Five-Quarter Moving Average	Percentage of Centered Moving Average
1	'73	1	7,726	--	--
2	'73	2	8,109	--	--
3	'73	3	8,610	7,239.0	118.94
4	'73	4	7,481	6,588.8	113.45
1	'74	5	4,269	5,917.4	72.14
2	'74	6	4,475	5,023.4	89.08
3	'74	7	4,752	4,162.4	114.16
4	'74	8	4,140	4,008.2	103.29
1	'75	9	3,181	3,832.4	83.00
2	'75	10	3,493	3,485.0	100.23
3	'75	11	3,596	3,251.0	110.61
4	'75	12	3,015	3,549.8	84.93
1	'76	13	2,970	3,849.2	77.16
2	'76	14	4,675	4,363.6	107.14
3	'76	15	4,990	5,677.2	87.90
4	'76	16	6,168	5,817.8	106.02
1	'77	17*	9,583	5,421.8	176.75
2	'77	18	3,673	5,093.6	72.11
3	'77	19	2,695	4,258.8	63.28
4	'77	20	3,349	3,267.2	102.82
5	'77	21	1,994	--	--
6	'77	22	4,575	--	--

*Combined tonnage--change of Federal fiscal year

Source: Croxton, Cowdren, and Klein, loc. cit.

TABLE F.5

PERCENTAGE OF CENTERED FIVE-QUARTER MOVING AVERAGES FOR SECOND DESTINATION TONNAGE, SOUTH/SEALIFT (Series #10)

Fiscal Year	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
73	--	--	118.94	113.54
74	72.14	89.08	114.16	103.29
75	83.00	100.23	110.61	84.93
76	77.16	107.14	87.90	106.02
77	176.75	72.11	63.28	102.82

Source: Table F.4

TABLE F.6

ARRAY OF PERCENTAGES

Rank	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Mean
1	176.75	107.14	118.94	113.54	
2	83.10	100.23	114.16	106.02	
3	77.16	89.08	110.61	103.29	
4	72.14	72.11	87.90	102.82	
5	--	--	63.28	84.93	
Mean of ranks 2 & 3	80.1	94.7	112.4	104.7	97.975
Seasonal index	81.8	96.6	114.7	106.9	100.0

Source: Table F.6

TABLE F.7

ACTUAL ERROR IN TONS AND PERCENTAGE ERROR
FOR NE/SEALIFT (Series #8)

Quarter	Seasonal Index	Forecast ($\bar{x}$ Multiplied by Index)	Actual 3rd Qtr. 1978	Percentage Error	Actual Error (Tons)
First	332.6	9,801	--	--	--
Second	33.6	666	--	--	--
Third	23.2	684	318	-115.1%	-366
Fourth	21.6	637	--	--	--

Note: The mean of the series used was $\bar{x}$ = 2,946.9

TABLE F.8

ACTUAL ERROR IN TONS AND PERCENTAGE ERROR
FOR SOUTH/SEALIFT (Series #10)

Quarter	Seasonal Index	Forecast ($\bar{x}$ Multiplied by Index)	Actual 3rd Qtr. 1978	Percentage Error	Actual Error (Tons)
First	81.8	3,825	--	--	--
Second	96.6	4,516	--	--	--
Third	114.7	5,363	7,231	25.8%	1,868
Fourth	106.9	4,998	--	--	

Note: The mean of the series used was $\bar{x}$ = 4,674.5

ANNEX G

POLYNOMIAL REGRESSION VERSUS TIME

Tables G.1 and G.2 give the results obtained from regressing the tonnage series versus time. Table 6.1 gives the results for a first-order polynomial (i.e., a straight line). Table G.2 gives the results for a second-order polynomial (i.e., a quadratic). It is not recommended to go beyond a quadratic in developing forecasting models using time as an independent variable. In terms of goodness of fit as measured by R^2, PAC/SEA (Series #6), ALA/SEA (Series #7), EUR/SEA (Series #9), and SOUTH/SEA (Series #10) perform remarkably well.

TABLE G.1

STRAIGHT LINE REGRESSION VERSUS TIME (t)

No.	Series	N	R^2	Regression Equation	Predicted Tonnage	Actual Tonnage	% Error
1	PAC/AIR	24	0	Y = 1891 - 0.2t	1,886	2,011	6.2
2	ALA/AIR	72	0.03	Y = 645 - 0.768t	589	565	- 4.2
3	NE/AIR	24	0.04			228	
4	EUR/AIR	72	0			2,506	
5	SOUTH/AIR	54	0	Y = 109 - 0.105t	103	97	- 6.2
6	PAC/SEA	23	0.76	Y = 133,000 - 4026t	36,376	35,054	- 3.8
7	ALA/SEA	23	0.55	Y = 7080 - 196t	2,376	3,823	37.8
8	NE/SEA	23	0	Y = 3960 - 84.5t	1,932	318	--
9	EUR/SEA	23	0.66	Y = 84904 - 1566t	47,320	40,047	-18.2
10	SOUTH/SEA	23	0.39	Y = 6672 - 166.5t	2,676	7,231	63.0
11	CONUS	45	0.03	Y = 1926 - 1.24t	1,869	1,475	-26.7

TABLE G.2

QUADRATIC REGRESSION VERSUS TIME (t)

No.	Series	N	R^2	Regression Equation	Predicted Tonnage	Actual Tonnage	% Error
1	PAC/AIR	24	0.07	$Y = 2010 - 27.8t + 1.1t^2$	2,003	2,011	0.4
2	ALA/AIR	72	0.23	$Y = 542 + 759t - 0.114t^2$	489	565	13.5
3	NE/AIR	24	0.01			228	
4	EUR/AIR	72	0.13			2,506	
5	SOUTH/AIR	54	0.02	$Y = 101 + 0.732t - 0.0152t^2$	67	97	30.9
6	PAC/SEA	23	0.77	$Y = 135000 - 4512t + 20.3t^2$	38,405	35,054	- 9.6
7	ALA/SEA	23	0.63	$Y = 8414 - 517t + 13.4t^2$	3,724	3,823	2.6
8	NE/SEA	23	0.02	$Y = 4002 - 94.5t + 0.417t^2$	1,974	318	--
9	EUR/SEA	23	0.70	$Y = 78486 - 25.1t - 64.2t^2$	40,904	40,047	- 2.1
10	SOUTH/SEA	23	0.54	$Y = 8434 - 589t + 17.62t^2$	4,436	7,231	38.7
11	CONUS	45	0	$Y = 1900 - 2.18t - 0.0743t^2$	1,843	1,475	-24.9

ANNEX H

THE WIENER-KOLMOGOROV METHOD

The Wiener-Kolmogorov (WK) method is a spectral autoregressive method.* It is used here because in theory it is superior to other methods such as autoregressive regression. One of its disadvantages, however, is that it requires a long series for parameter estimation. (The same is true of the Box-Jenkins model; but one can always choose the latter by guessing or by trial and error).

*See Chan, K. H. and J. C. Hayya, "Spectral Analysis in Business Forecasting: The Wiener-Kolmogorov Method," Decision Sciences, Vol. 9, No. 4 (October 1978), pp. 700-711.

TABLE B.1

RESULTS OBTAINED USING THE WIENER-KOLMOGOROV METHOD

Series	Name	N	Model Fitted (t = 1 for July '72)	Prediction for July '78 (t = 73)	Actual for July '78	Forecast Error
#1	PAC/AIR	69	$X_t = 8028 - 112.66t + 0.9196X_{t-1} + 0.0289X_{t-2} + 0.0771X_{t-3} - 0.3234X_{t-4} + 0.3456X_{t-5}$	1781	2011	11.4%
#2	ALA/AIR	69	$X_t = 654 - 1.17t + 0.4720X_{t-1} - 0.0120X_{t-2} + 0.2828X_{t-3}$	956 (568)	565 "	-69.3 (- 0.5)
#3	NE/AIR	69	$X_t = 575.54 - 48092t + 0.00846X_{t-1} + 0.2550X_{t-2} - 0.1302X_{t-3} + 0.1252X_{t-4} + 0.1501X_{t-5} - 0.1592X_{t-6}$	319 (224)	228 "	-39.9 (1.8)
#4	NE/EUR	69	$X_t = 2932 - 7.3431t + 0.3892X_{t-1} + 0.1853X_{t-2} - 0.0274X_{t-3} + 0.0011X_{t-4} + 0.0685X_{t-5}$	4121 (2954)	2506	-64.4 (-17.8)
#5	SOUTH/AIR	69	Experimentation not successful			
#11	CONUS	67	$X_t = 1945.7 - 2.3031t + 0.4602X_{t-1} - 0.0317X_{t-2} - 0.1203X_{t-3} - 0.1380X_{t-4} + 0.1085X_{t-5}$	2437 (1778)	1475	-65.2 (-20.5)
#17	WFH	69	$X_t = 342610 - 2464.2t + 0.5082X_{t-1} + 0.2501X_{t-2} - 0.1614X_{t-3} - 0.0060X_{t-4}$	303916 (162723)	222754	-36.4 (26.9)

Note: The numbers in parentheses refer, respectively, to forecasts and forecast errors using only the mean and trend components (i.e., the first two terms of the formula). This we shall call the "truncated WK model."

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